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METERING SECONDARY WATER IN RESIDENTIAL IRRIGATION SYSTEMS

by

Gregory L. Richards

A thesis submitted in partial fulfillment
of the requirements for the degree

of

MASTER OF SCIENCE

in

Civil and Environmental Engineering

Approved:

Michael C. Johnson
Major Professor

Steven L. Barfuss
Committee Member

R. Ryan Dupont
Committee Member

Byron R. Burnham
Dean of Graduate Studies

UTAH STATE UNIVERSITY
Logan, Utah

2009

ABSTRACT

Metering Secondary Water in Residential Irrigation Systems

by

Gregory L. Richards, Master of Science

Utah State University, 2009

Major Professor: Michael C. Johnson
Department: Civil and Environmental Engineering

The use of residential secondary or dual water systems for irrigation purposes is common in the western United States where water supplies are scarce. While the use of non-potable water in secondary systems has successfully curtailed demands on potable systems, experience has shown that overall water use actually increases with the introduction of a secondary supply because users commonly pay a fixed fee and have unlimited water use. While water metering and billing effectively reduce water use, there are two main obstacles to the widespread installation of meters in secondary systems.

The first obstacle is that standard residential water meters do not normally function in debris-filled secondary water. Metering mechanisms can clog or be degraded by suspended debris of both organic and inorganic nature in the water. By way of innovative meter designs or filtration, a few secondary systems have had success metering their secondary water. Other systems have experimented with possible debris-resistant meters but have had little success.

In addition to the physical limitations of water meters, secondary systems face economic obstacles from the increased expense of metering. Since secondary water is intended to be an inexpensive alternative to potable water for outdoor irrigation, any cost increase due to the expense of meters, filtration, meter reading, etc., interferes with the main objective of a secondary system. A system-specific economic analysis is necessary to determine the financial feasibility of the implementation of metering in any secondary system.

The objective of this research is to identify feasible ways for metering secondary water systems. An overall analysis is made of the performance, benefits, and drawbacks of each technological approach. Approximate costs and design requirements of these technologies are identified, thereby allowing water suppliers to determine the economic feasibility of metering. In addition, other design precautions for implementing secondary metering and investigations of residential meter performance in secondary systems using filtration are discussed.

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Gregory L. Richards

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LIST OF SYMBOLS AND ABBREVIATIONS

List of Symbols

F	Cost of filtration per connection (\$)
I_l	Cost of installation labor for one connection (\$)
I_m	Cost of installation materials (\$)
L	Expected life of the meter and filter (years)
M	Cost of the meter (\$)
MR	Cost of the automatic meter reading device (\$)
OM	Monthly operation and maintenance costs (\$)

List of Abbreviations

AMR	Automatic meter reading
AWWA	American Water Works Association
gpcd	Gallons per capita per day
gpm	Gallons per minute
in	Inches
mg/L	Milligrams per liter
PPM	Parts per million
TSS	Total suspended solids
WBWCD	Weber Basin Water Conservancy District

CHAPTER I

INTRODUCTION

Water is one of our most precious and vital resources. With a rapidly growing population, a desert climate, and delicate ecosystems at risk; the state of Utah has furthered its efforts to conserve water. In 2001, the Utah Division of Water Resources officially issued a state-wide goal to reduce water demand of public community systems by 25 percent by the Year 2050 (Utah DWRe, 2001). As seen in Figure 1, the 25 percent reduction in per capita water use is critical in meeting future demands. Even with that conservation effort, the existing supply will likely fall short.

The state plans to achieve this goal by implementing many “water-wise” practices, many of which are already in effect. Its large-scale media campaign focuses on conservation awareness and has proved to be very successful. This includes the creation of an informative website, several media commercials, and a water-wise education program. Actual conservation actions include the use of native, water-efficient plants in landscaping (also known as “xeriscaping”), the introduction of water-efficient appliances, and the recommendation of water management practices that should be adopted by Utah water suppliers.

According to the Utah Division of Water Resources, approximately 45 percent of total public water supply in Utah is used for outdoor residential purposes (Utah DWRe, 2000). Many do not realize how much water they are using to maintain a green lawn. Due to the high percentage of water use that occurs outdoors, many of recommended

Figure 1 Projected water deficits in Utah for Year 2050 (Utah DWRe, 2001)

water management practices are aimed at dual water systems, or systems that provide a substantial amount of outdoor irrigation water to residential users.

Traditionally, the installation and use of dual water systems has been a favorably-viewed water management approach in the state. Dual systems, also known as secondary water systems, provide one connection for potable water and another connection for secondary or non-potable irrigation water. By using an untreated water supply for outdoor irrigation purposes, users are provided a less-expensive method of landscape irrigation while high-quality potable supplies are conserved for indoor use. Despite these benefits, the recent water conservation push has drawn attention to the fact that nearly all secondary systems are unmetered. This lack of metering corresponds to irresponsible water use. In other words, secondary water users use significantly more water than necessary.

Due to debris in secondary water systems, the strainers and mechanical moving parts of conventional water meters (such as the piston-type meter shown in Figure 2) become clogged and malfunction when installed in a secondary system. Modern technology has provided alternative ways to measure water flow that do not pose a problem to secondary systems, however, these meters can cost thousands of dollars while standard residential meters cost \$200 or less. Due to a lack of accurate and economical measurement, secondary water users do not pay for the amount of water used, rather they pay for an annual share of water. This fee is often based on lot acreage or connection size. Since users hold no accountability for the amount of water used, over-watering and waste occur.

The objective of this research is to identify feasible ways for the metering of secondary water systems. The exploration of possible solutions such as filtering stations, alternative water meters, and improved secondary water quality is discussed. Alternative water metering technologies that are capable of passing debris may well be the most

Figure 2 Typical piston-type meter interior (Sensus, 2004)

direct solution. Another option is the use of filters to clean secondary water sufficiently in order to use ordinary residential water meters. The experiences of several metered systems are summarized (Appendix A).

In addition to the physical limitations of water meters, secondary systems face economic obstacles from the increased expense of metering. Since secondary water is intended to be an inexpensive alternative to potable water for outdoor irrigation, any cost increase due to the expense of meters, filtration, meter reading, etc., interferes with the main objective of a secondary system. A system-specific economic analysis is necessary to determine the financial feasibility of metering in any secondary system. Meter and filtration cost information as well as other economic considerations are discussed.

CHAPTER II

LITERATURE REVIEW

Due to the recent nature of the problem, existing literature concerning secondary metering is limited. The Utah Division of Water Resources has prepared two unpublished reports about secondary metering. One of these reports outlines their failed efforts to meter secondary water using a paddle-wheel-type meter (Utah DWRe, 2004b). The other summarizes the physical and economic requirements of a secondary water meter, but it fails to identify an existing meter that will meet all requirements (Miller, 2001).

There are also two previous studies performed at the Utah Water Research Laboratory concerning secondary metering. Kartik examines the feasibility of manufacturing a deflection-type water meter for use in debris-filled systems (Kartik, 1997). This study concludes that the theoretical design of a strain- or deflection-type meter would function properly in a debris-filled system and would cost approximately \$200 per meter if manufactured commercially. However, the study also cites several possible limitations of the meter including its endurance in a freezing environment as well as the necessity of improved water-proofing and protection of electronic components. The final design and manufacture of such a meter would have to be performed by a facility with commercial fabricating capabilities. No known company has further investigated such meter design.

The other study from the Utah Water Research Laboratory was conducted by Ammon Allen. The project included laboratory testing on both single-jet and fluidic-oscillator-type meters to simulate conditions typical of a secondary system such as interior and exterior freezing, mineral buildup, and the passing of debris (Allen, 2008). It is

concluded from this study that both the Actaris single-jet and the Severn-Trent fluidic-oscillation meter are capable of metering in a variety of harsh environments that can be common in secondary systems, including that of debris-filled water. The study does concede, however, that the accuracies of meters tested in actual secondary systems have shown a decrease over a few years of use. It was recommended to perform laboratory testing of these meters in adverse conditions over a much longer period of time to determine their actual capabilities in secondary water.

The remainder of existing information about secondary water metering consists of a piecing-together of the experience of irrigation companies and municipalities. A few systems, such as Spanish Fork City and Grantsville Irrigation Company, have successfully metered water by using filtration. The Utah Division of Water Resources has also performed field testing on the fluidic-oscillation-type meter, but results of this testing have been obtained only through personal communications. No formal reports of the meter's performance in a dual system have been prepared.

While all of the previously-cited reports have provided useful insights into secondary water metering, none has identified a conclusive and proven solution to the problem or discussed in detail the option of filtration. This thesis will outline technological approaches that currently allow metering as well as their costs. It will also attempt to provide a useful guide to secondary water providers that are interested in determining the feasibility of metering their systems.

CHAPTER III
METERING SECONDARY WATER IN RESIDENTIAL
IRRIGATION SYSTEMS*

ABSTRACT

The use of residential secondary or dual water systems for irrigation purposes is common in the western United States where water supplies are scarce. While the use of non-potable water in secondary systems has successfully curtailed demands on potable systems, experience has shown that overall water use actually increases with the introduction of a secondary supply because users commonly pay a fixed fee and have unlimited water use. Water metering and billing reduce water use; however, standard residential water meters do not normally function in debris-filled secondary water.

A few pioneering water suppliers are currently searching for a cost-effective way to meter secondary water. The purpose of this paper is to explore the current practices that water suppliers are using, including filtration and innovative meter designs, in order to conserve precious water resources. Their experiences show that not only is secondary metering a future necessity, but also a present possibility.

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INTRODUCTION

Rapid population growth has prompted much discussion over water issues in the arid western United States. The country's five fastest growing states (Nevada, Arizona, Colorado, Utah, and Idaho) also happen to be among the driest states in the nation (Utah DWRe, 2001; USDI, 2000). In order to sustain growth, sufficient water must be available. Water conservation is therefore a priority, and various techniques are being used to encourage conservation. For irrigation companies and other water providers, incentive pricing and increased efficiency of water distribution systems provide ways to conserve. Water efficient appliances and toilets, soil moisture and evapotranspiration sensors for automatic sprinkler systems, and increased acceptance of xeric landscaping practices have all contributed to reductions in residential water use.

Another common practice throughout the United States is the use of dual water systems. Dual systems, also known as secondary water systems, provide one connection for potable water and another connection for secondary or non-potable irrigation water. While not necessarily conserving water, secondary systems significantly decrease the use of potable water. Despite this benefit, the recent conservation push has drawn attention to a negative aspect of using non-potable water for irrigation. This non-treated water typically contains debris in the form of suspended organic and inorganic matter. Conventional water meters used in secondary systems can become clogged, and suspended grit can wear away mechanical meter parts. Additionally, secondary systems that are drained during winter months are subject to a hardened buildup of mineral and other deposits. This buildup hinders the free movement of mechanical meter parts when the system is pressurized in the spring (Utah DWRe, 2004a).

Historically, unmetered secondary water systems have used a fixed-rate fee system. Users generally pay a fee based on land acreage or connection size for their use of untreated water. While potable water use is decreased with the introduction of secondary systems, overall water use increases. Studies have shown that excessive watering is common where water use is not metered, with some users watering their lawns up to twice the needed amount (Utah DWRe, 2004b). A way to increase user accountability is required in order to reach conservation goals and meet near-future water demands. The state of Utah has shown its awareness of this problem in Utah's Municipal and Industrial Water Conservation Plan for the Year 2003. In the plan, secondary water providers are advised to charge for secondary water based on individual use levels as soon as technology permits.

Either by their own efforts or with assistance from the Utah Division of Water Resources (Utah DWRe), a few secondary water providers have begun metering secondary water. Hindrances to metering secondary water, as well as accounts of those who are currently metering their systems, are summarized in this study.

DUAL SYSTEMS

A brief history. In 1995, 67 percent (an amount equaling 143 gallons per capita per day) of all water used for residential purposes in Utah was used outdoors – that is nearly half of the total public supply of water (see Figure 3). Unpublished statistics for 2005 from the Utah Division of Water Resources indicate similar results (Williams, 2007), and parallel trends occur in other desert states (SNWA, 2007; Mecham, 2003). In order to reduce the demand on limited potable water supplies, many communities have installed secondary water systems to provide irrigation water.

Secondary water systems are in no way a new idea. In fact, one of the first dual distribution systems was built in Rome as early as 40 AD. While certain aqueducts provided drinking water supplies, others conveyed water of an inferior quality to be used for bathing, irrigation, and decorative fountains (AWWA, 1983). The idea of a secondary water system was first introduced in the United States in the early twentieth century, but it did not rise in popularity until recently. The first secondary distribution system in the United States was built in the 1920s in Grand Canyon Village, Arizona. Since rainfall and freshwater supplies were limited, rapidly growing demands spurred the development of a secondary system (Okun, 1997). In this system, non-potable recycled wastewater was used for irrigation purposes as well as toilet flushing. St. Petersburg, Florida lays claim to the development of the country's first major dual system in 1969. Due to saltwater intrusion into overdrawn aquifers and a limited supply of surface water, St. Petersburg implemented this system in order to meet the demands of its booming

Figure 3 Breakdown of 1995 publicly supplied water use including secondary water

Table 1 Estimated secondary system water use by Utah county

County	1992		2001		Increase in Water Use %
	Number of Systems	Water Use acre-ft	Number of Systems	Water Use acre-ft	
Davis	12	28,500	34	43,418	52
Morgan	7	200	16	240	20
Summit	15	1,800	30	1,637	-9
Weber	17	27,400	44	40,757	49
Basin Total	51	57,900	124	86,052	49

population. In this system, recycled wastewater is the secondary water source (Okun, 1997). Similar systems in Florida are supplied by a mixture of recycled wastewater and untreated canal water (Godman & Kuyk, 1997).

Today, many dual systems exist in the arid western states. Although several of these use recycled wastewater as their primary source, a large portion use runoff and groundwater. In order to meet demands throughout an entire irrigation season, high spring runoff flows are collected and stored in open-air reservoirs. The Weber River Basin in Utah is home to one of the most complete secondary systems in the country. This system has doubled in size over the past ten years (see Table 1). In 2003, approximately 43 percent of municipal and industrial water demand and 68 percent of the total outdoor water demand in the basin was provided through secondary water systems (Utah DWRe, 2004c).

Experience has shown that dual systems effectively conserve potable water by providing non-potable water for irrigation. They do require the construction of additional infrastructure, however, which is usually costly. While secondary systems are less likely to be installed in existing developments, they are usually cost-effective to install in areas

of new development. Secondary water systems may also be economical if their construction costs are less than the cost of expanding the potable water supply system to meet future indoor and outdoor demands (Utah DWRe, 2004a).

Dual systems and outdoor water use. Secondary water systems have been successful in reducing potable water use; however, statistics show that overall water use drastically increases with the introduction of unmetered secondary systems. This increase in use occurs because of fixed-fee water pricing and a lack of user accountability. A recent five-year study performed by the Utah Division of Water Resources determined that unmetered secondary water users generally use 47 percent more water than necessary to sustain a healthy, green lawn. One documented user watered over two and a half times the amount needed (Utah DWRe, 2004b). The Utah State Water Plan further validated this concern associated with secondary water systems. Their findings show that the five basins with the highest overall per capita use in Utah are also the five basins with the highest residential outdoor per capita use of non-potable water (see Figure 4). This indicates that consumers use more water outdoors in basins where inexpensive unmetered secondary water is available (Utah DWRe, 2001).

Metering. Colorado State University performed a study in 2003 on the benefits and costs of pressurized dual water systems. Their study also explored the influence of metering secondary water. The study found that although residential indoor water demand has been found to be relatively inelastic (not susceptible to changes in use due to metering), outdoor use does change with the use of meters. Water use of residences with meters is usually lower than water use of residences that are charged a flat rate. The

Figure 4 Residential outdoor water use in Utah by basin

majority of this reduction is in outdoor water use. The study shows that over an average of six years, flat rate users expended about 39 percent more water than those who were metered (CSU, 2003).

Perhaps the simplest solution to excessive outdoor use and abuse is metering. The Utah Water Plan indicates that one way to deal with over-use is to meter the water and charge according to an incentive pricing rate structure (Utah DWRe, 2001). St. Petersburg, Florida reports that unmetered reclaimed water has been excessively wasted, and plans are underway to retrofit meters on all services (Okun, 1997).

PROBLEMS WITH SECONDARY WATER METERING

Finding a suitable meter. Modern technology has provided ways to meter water that do not pose a problem to secondary systems. Two examples are the magnetic flow meter and the ultrasonic flow meter – meters that have no moving parts and can readily pass debris. These meters can cost thousands of dollars, however, whereas standard residential meters generally cost less than one hundred dollars. Accuracy, durability, and cost are important considerations for metering secondary water. Despite the inherent difficulties associated with secondary water metering, experimentation has not been inhibited. Existing and new meter technologies have been used, and filtration techniques have been utilized. Those experimenting in secondary water metering have exposed a variety of problems as well as possible solutions.

Secondary water quality. Perhaps the most obvious barrier to metering secondary water is the quality of the water. Secondary water generally comes from mountain runoff or groundwater wells from which the water has smell, taste, or turbidity issues. Because it is not treated and is usually stored in open-air reservoirs, secondary water tends to carry a significant amount of debris. Many systems that receive water from rivers or storage reservoirs contain a large amount of organic material (Taylor, 2007). Moss, leaves, snails, insects, crawfish, and fish have been found inside meters. When debris clogs or blocks a meter, it generally causes pressure loss, flow reduction, and flow measurement problems.

Secondary systems supplied by surface water, along with those supplied by groundwater, can also contain suspended sands and silts. Not only can sand and silt clog meters, but they can also wear out internal metering mechanisms resulting in decreased

accuracy and a shorter meter life (Utah DWRe, 2004a). In water quality conditions such as these, either a meter must be immune to suspended solids, or adequate filtration must protect it.

Thus far it has proven difficult to find a meter that is unaffected by debris. Meters with no moving parts have an advantage in that they are resistant to plugging and degradation. Magnetic and ultrasonic flow meters are debris tolerant because debris readily passes through them and there are no wetted moving parts. Unfortunately, as stated previously, meters using these technologies are expensive and have significant power supply requirements. Fluidic-oscillation meters and single-jet turbine meters have also shown promise in handling debris (Stephens, 2007).

While meters suitable for secondary water are still being developed, advanced filtration technologies provide a wide variety of options for treating secondary water. From simple screens that keep out large debris at the source to self-cleaning automated filter stations, the broad array of available filtration technologies can meet most secondary water treatment requirements. A major filter manufacturer¹ suggested a filtration degree of 80 microns in secondary water applications but also indicated that the final filtration degree would have to be based upon the recommendations of the water meter manufacturer or based on the smallest orifice size in the water meter (Maher, 2008).

Harsh environment. Irrigation meters are generally installed in sprinkler boxes one to two feet below ground surface, providing little protection against freezing in colder climates. Even meters buried several feet below ground surface can be subject to freezing. Most systems are drained at the end of the irrigation season, but small amounts

of water and moisture can remain in the meter. Freeze plates on the bottom of meters are a common safeguard against this problem.

Because the meters are drained for several months in a year, a layer of organic and inorganic buildup hardens on the meter interior, hindering the movement of mechanical parts when the system is again pressurized. The nature of the buildup is dependent primarily on water quality.

Physical environment can continue to impede water metering during warmer seasons as well. Poor drainage and over watering commonly result in sprinkler boxes and meters being submerged in water. If the meter's registry system or electrical components are not watertight, the meter can fail.

Meter power requirements. In addition to their cost, magnetic and ultrasonic meters are prohibitive to most residential metering applications because of their power requirements. Ideally, a meter should be self-contained and have battery life of five to ten years. Batteries with a life of less than five years become labor intensive, decreasing the cost-effectiveness of the meter. Several meters on the market using battery power claim to have batteries that will last at least ten years.

SECONDARY WATER PROVIDERS

Most communities with secondary water service as well as those planning the construction of a secondary system have considered the possibility of metering. The benefits of metering potable water are proven; however, the benefits of metering secondary water remain economically disputable. The cost of metering technology suitable for secondary water conditions has already been discussed. In secondary water markets, any cost increase interferes with inexpensive water pricing schemes. If non-

potable water does not cost less than potable water, there is no incentive to decrease potable use and, therefore, no point in operating a secondary water system. Economic feasibility seems to be the roadblock to metering for most secondary water providers.

While most secondary water suppliers have made little or no effort to meter their water, a few suppliers have taken the initiative, often with government assistance, to meter their secondary water. The Weber Basin Water Conservancy District and a few communities along Utah's Wasatch Front have participated in an ongoing effort headed by the state to find a suitable secondary water meter. The city of Spanish Fork, Utah is currently metering its entire secondary system with conventional potable water meters. In the Spanish Fork system, a centralized filtering station cleans the water sufficiently to make metering possible. Grantsville Irrigation Company uses a similar approach, except that individual filters are installed at each connection. State of Utah metering experiments and the experiences of systems implementing secondary water metering have provided valuable information about how to meter secondary water.

State of Utah metering experiments. As the driving force in most metering experiments, Utah's Division of Water Resources has researched, donated, and monitored hundreds of test meters in various secondary water systems around the state. Chief among these test systems is the Weber Basin Water Conservancy District (WBWCD).

WBWCD, the state's largest secondary water provider, serves about 40,000 secondary residential connections and approximately 80,000 more through wholesale water deliveries. Their secondary water comes from the Weber River drainage basin, four wells, runoff from nearby canyons, and a few springs. They have found that water quality is dependent on the location of the source as well as the time of year. Organic

debris commonly found in WBWCD's system includes moss, algae, and snails. Their water also contains sand and sediment eroded from canyon sources during high spring runoff flows. Sand and sediment settle in the bottom of main water lines when velocities are low in the spring, and as demand increases in the summer, high velocities carry it through the system (Hess et al, 2007).

Larger pieces of debris are kept out of WBWCD's secondary water system by a settling pond and a screen with 1/4-inch openings. Although it is not mandated by the water district, many secondary water users install small filters in their systems. Sometimes customers complain that they are unable to run a single cycle on their sprinkler systems without their filters clogging completely (Hess et al, 2007).

WBWCD has participated in a state-sponsored study for several years to find a meter suitable for secondary water measurement. They recognize the benefits of water conservation, but economic obstacles still discourage widespread secondary metering. Not only does the initial cost discourage metering, but a significant number of new employees would also be required in order to maintain the system. This would be economically difficult even for a large water district such as WBWCD. For most other smaller irrigation companies, the implementation and maintenance costs associated with metering limit its use.

Currently, WBWCD's secondary system is easy to manage and operate without metering. However, WBWCD realizes that before they spend millions of dollars to import water from other hydrologic basins, they will need to use all the water within their own basin efficiently. In this case, secondary water metering would be obligatory. While WBWCD is not looking forward to the day of secondary water metering, they do

realize that it is an eventuality and are therefore interested in possible solutions that will help them prepare to implement complete secondary system metering (Hess et al, 2007).

As part of the state's research, several paddle-wheel type water meters were installed in WBWCD's system in 2000. These 4-inch meters were installed to monitor small cul-de-sacs or dead-end areas. Due to difficulties with calibration and debris, most of the meters failed within the first season of use. This type of meter was abandoned, and its manufacturer has since discontinued the product. The Division of Water Resources then approved the purchase of several magnetic meters. These meters allowed for the completion of another portion of their study (determination of water usage compared to that needed to efficiently maintain the landscape), but the high cost and short battery-life rendered them inadequate for any other use (Utah DWRe, 2004b).

Recently, the state provided 30 fluidic-oscillator meters² for testing on individual homes in WBWCD. This type of meter offers promise in its design and its price (\$100 per meter). The fluidic-oscillation-type meter contains no moving parts to foul or clog. As described in AWWA Standard C713-05, flowing water enters the meter through a converging entrance nozzle that forms a jet flow. Two diverging walls produce opposing forces on the jet flow due to the Coanda effect and cause the jet to oscillate. Each oscillation corresponds to a specific volume of water flowing through the meter and is electronically detected, integrated, and displayed in the register (AWWA, 2005). Meters employing this technology were initially expensive, but recent advances in electronics have made fluidic-oscillator meters feasible for residential metering applications. The manufacturer's claims that the meter is unaffected by grit as well as positive results from endurance testing sparked Utah's interest in the meter.

Despite large amounts of debris in their water, it is significant to note that WBWCD has not had any complaints about the fluidic-oscillation-type meters clogging (Hess et al, 2007). Out of the 30 meters installed, only two have failed after an entire year of operation (Stephens, 2007). One of them had a dead register (since this type of meter has a digital register, it was probably due to an electronic issue), and one of them had a cracked base. This meter was still metering water despite the fact that it leaked. The failure was probably due to freezing in the winter. Further investigations revealed that only a portion of the fluidic-oscillator meters have potted (protectively sealed) electronics (Searle, 2007). This extra protection may improve the performance of the digital register in underwater situations.

Two other significant water systems, the City of Draper and Grantsville Irrigation Company, were included in the state's study of fluidic-oscillator meters. The city of Draper's secondary water system is run by a private non-profit company called WaterPro Incorporated. The system, installed in 1994, is supplied entirely by surface water sources (Gardner, 2007).

Unlike many secondary water providers, WaterPro Inc. is very interested in metering all secondary water connections as soon as possible. As a growing, mid-sized system already running at near capacity, conservation through metering would allow them to extend their service without much more expense. However, this universal metering goal is still far out of reach economically for WaterPro Inc. In order to reach this goal, they are hoping that the state government will soon provide grants, rebates, or other incentives to allow the introduction of widespread metering. The drawback to secondary metering

for Draper is the increased workload in areas such as billing, meter repair, and meter reading.

In light of their interest in secondary metering, WaterPro Inc. also maintains relations with several meter manufacturers, and they have installed a few test meters given to them by these manufacturers. In all, they have installed nearly 20 fluidic-oscillation-type meters from the state of Utah and three single-jet meters given to them by two different water meter manufacturers.³ While fluidic-oscillators do not have moving parts, single-jet meters have an impeller that is turned by a jet of water as it passes through the meter. The rotational speed of the rotor is proportional to the flow rate. So far, there have been no problems with the single-jet meters, although the limited size of the sample gives little statistical credibility and further research should be done. Two of the fluidic-oscillator meters have failed due to electrical problems (Gardner, 2007).

Grantsville Irrigation Company was also given 25 fluidic-oscillator meters to be tested. Out of the 25 meters provided to the irrigation company, three have had battery or electrical failures in the past five years. They have also had problems with the meters freezing. Currently, 18 fluidic-oscillator meters remain in the system (Taylor, 2007).

Another problem associated with secondary water metering is that of public acceptance. According to Jeff Morgan, Inspector for WBWCD, it was difficult to find 30 residences to participate in the fluidic-oscillator study. The public in general responded with reluctance and unease. In Draper, volunteers were requested in a monthly newsletter. When only 15 residents responded, the remainder of the meters were installed in new subdivisions where acceptance is generally easier to obtain (Gardner, 2007).

While a definite solution has not been found, the Utah Division of Water Resources' efforts to find a meter suitable for secondary water applications have resulted in a better understanding of the problems related to secondary metering. While most meters have either failed or are too expensive, the fluidic-oscillation-type meter has shown promise. Although apparently effective in debris-filled water, this type of meter is still in need of increased durability and protection of electrical components. It should also be noted that the effects of secondary water use on the accuracy of the fluidic-oscillator meters have not yet been investigated. Considering these findings, the state of Utah continues its testing with fluidic-oscillator meters and its search for additional metering possibilities.

Centralized filtering – Spanish Fork City, Utah. Spanish Fork City made the decision to upgrade its secondary water system in the early 2000s. Rather than spend over \$25 million for improvements on their culinary system to meet future demands, they chose to expand and update their secondary water system for \$17 million. This system, which now serves about 8,000 connections, has the capacity to serve over 19,000 connections (Nielson, 2007).

To serve their secondary water demands, Spanish Fork uses two wells that do not meet drinking water standards, two wells with smell or taste issues, and two new wells that meet culinary standards. These wells are viewed as only a temporary solution as a secondary water source. As soon as the Central Utah Project pipeline reaches Spanish Fork City, they will use water from Strawberry Reservoir as their primary secondary water source (Nielson, 2007).

Water is pumped from the city's wells to a 22 million gallon reservoir at the mouth of Spanish Fork Canyon. The reservoir has been converted to a public recreation area

providing a beach, camping sites, and a pavilion; it is also stocked with fish. This public area is viewed as a benefit to the community while still serving its primary purpose as a secondary water storage structure. After the water leaves the reservoir, it is filtered by one of three 80-micron filters.⁴ These filters have automatic self-cleaning features that reduce maintenance costs. Since Spanish Fork has experienced few problems with their meters, and the automatic cleaning mechanisms on their filters seem to be constantly running, they are going to increase the filter screens to 130 microns at the end of the 2007 irrigation season (Nielson, 2007). It is expected that this filtration level will sufficiently filter the water while decreasing power consumption and wear of the filter mechanisms.

Spanish Fork's system has been specifically designed to withstand the harsh effects of winter. For example, the lateral branches feeding each connection are sloped down towards the main line. By doing this, in theory, each meter and lateral branch is drained when the main is drained at the end of the season. The only problem with debris has been caused by backflow through discharge valves that have been left open for extended periods. An increased awareness of this maintenance issue has solved the problem.

Because the water is filtered to such a high level, Spanish Fork has been able to use standard residential water meters for secondary water purposes. They are currently using 3/4-inch multi-jet meters.⁵ Throughout an entire year, Spanish Fork replaces about six secondary meters – less than one-tenth of a percent of their secondary meters. The most common defects occur in the registry of the meter, probably due to lack of waterproofing. Since these meters are under warranty, maintenance costs are minimal. One to two full-time employees maintain all of the meters (culinary and secondary). With the present system, it takes three meter-readers to read all connections once a month. Within the

next two years, Spanish Fork expects to upgrade to an automatic meter reading (AMR) system. They have constructed a radio tower that will read both secondary and culinary water meters as well as electrical power meters (Nielson, 2007).

Overall, the system has been a success. The secondary system currently serves 7,336 connections – almost 90 percent of all culinary connections (8,332 culinary water connections). While water rates have been temporarily raised in order to pay off the project bond, they are expected to decrease dramatically within ten years (Nielson, 2007). If all goes as planned, Spanish Fork will have succeeded in actually lowering water rates while almost doubling their potable water system's service capacity.

Several other secondary systems are looking into the possibility of centralized filtering (Bushman, 2007). Riverton City, Utah is currently filtering all secondary water to 100 microns, but has yet to find a meter manufacturer who will uphold a warranty on their meter (Dalton, 2007). (It is important to note that not all metering companies will guarantee their meters in secondary water conditions, even if the water is filtered.)

Individual connection filtering – Grantsville Irrigation Company. While centralized filtering has proven to be an effective approach for Spanish Fork, many smaller systems find that it is not economical. Grantsville Irrigation Company is one of these smaller systems in which centralized filtering is not an economically viable option. Serving roughly 1,400 connections, many of which are large agricultural water connections, the cost of a centralized filtering unit is more expensive per customer compared to individual filter units at each connection (Taylor, 2007).

Water for Grantsville's pressurized irrigation system is supplied by runoff from six canyons west of Grantsville, Utah. This runoff is collected and stored in a 3,400 acre-

foot reservoir located five miles south of the town. Since only three employees maintain the entire system and do all installations, they presently do not meter all connections. Of the 1,400 connections, they have installed about 540 meters, are converting old connections into metered connections, and are installing secondary water meters at all new residences. A standard connection in Grantsville consists of a valve, filter, two drains, and a meter. The entire connection is contained in one or two valve boxes (Taylor, 2007).

Grantsville has moved toward universal metering because of water abuse. Lynn Taylor, water supervisor of Grantsville Irrigation, believes that people do not purposely waste water, but that they are unaware of how much water they actually use. Over their past five years of metering, they have found several water abusers. One shareholder owning three shares of water used nearly eight shares in one season. The irrigation company considers such misuse a justification for metering, despite its added cost.

Grantsville knew that some type of filtration would be necessary in order for standard water meters to function; however, in analyzing the feasibility of a centralized filtering station, several problems were discovered. Grantsville must provide water to a wide variety of secondary water users. For example, farms and residential homes are interspersed, both on the same pressurized line. Since main line breaks occur frequently on farms where irrigation lines are exposed, dirt and other debris are allowed to enter water lines and potentially damage meters.

Another reason that a centralized filtering station is not feasible for Grantsville is that it is not economically justifiable for their system. Grantsville is a relatively small system with 1,400 connections with a possible growth of an additional 4,000 connections in the

next 20 years. Given the estimated flow rates and considering only the initial costs of filtering, it was significantly more economical for Grantsville to buy individual filters at about \$60 per connection as opposed to more than \$100 per connection for a centralized filtering station. In larger Spanish Fork, where a centralized filter has been installed, the initial price for filtering per connection is about \$40. It is evident that the number of connections served and the flow rate of each connection influences the type of filtering that will most effectively meet a particular system's needs.

For economic reasons, Grantsville chose to use individual filters for each connection. They began using screen filters, which pass water through a perforated metal cylinder. They soon discovered that the circular holes of these filters filled up much too quickly with debris and impeded the flow of water. In addition, these filters were only available in a model that must be glued into the line, making maintenance and replacement difficult. They then changed to 1-inch and 1½-inch compact filters. These filter to 250 microns and cost about \$60 apiece. Initially, they used a disc element as a filtering media. This filter greatly improved the flow of the system and seemed to do a better job than the screen filter. With time, however, they still experienced problems with the filter plugging. They continued using the same filters but changed the filtering media to a stainless steel mesh. Although harder to clean than the disc filter, this media has performed acceptably (Taylor, 2007).

Grantsville has many problems with debris such as snails, moss, and crawfish. One reason that the filter-clogging debris is such a problem is that the irrigation company cannot maintain the individual filters on every connection. The maintenance costs associated with the filters are one of the reasons that Spanish Fork dismissed the idea of

individual filtering. Grantsville gives the customer the responsibility to clean the filter. The smaller size of the irrigation company's system allows for greater control in seeing that this maintenance is done. Some users regularly clean the filter every week, while others report that it is only necessary every few months.

Invariably, a few customers refuse to maintain their filter. Half a dozen users have actually pulled the filter cartridge out in order to avoid filter maintenance. This allows the unfiltered water to go through their system, potentially ruining the water meter. Grantsville Irrigation policy treats this as an act of vandalization, and water users who have done this are held responsible for the meter.

Grantsville has used a variety of water meters including some experimental fluidic-oscillator meters as well as some nutating-disc meters. Currently they are using vertical turbine meters⁶ that seem to be working well. The only problem that they have experienced so far with the vertical turbine meters is freezing during the winter. The meters are designed to break out the bottom if they do freeze, and several freeze plates have been replaced. Some have also frozen out the top of the meter. In the particularly harsh winter of 2006-2007, they replaced more than ten meters (Taylor, 2007).

One way that Grantsville has alleviated freezing problems is by installing automatic drains that begin draining the system once the line pressure drops below a certain point. This has helped, but seeking further improvements, they have started installing an additional drain. Both sides of the meter are now protected by drains. The irrigation company reports that no problems have been experienced from debris buildup on the moving parts of any of the meters, although examination of a nutating-disc meter showed that debris buildup is present.

The economic success of Grantsville's metered irrigation system is still in question. In view of the conservation benefits and increased manageability, Lynn Taylor believes the system to be a success. When maintenance and meter replacement costs are considered, the economic and overall success of the system will only be determined with time.

CONCLUSIONS

With rapid growth and limited water supplies, many water systems throughout the United States and in particular those in western states are aware of the need for water conservation. Supplying secondary water is an approach that reduces demand on potable water and allows for more connections. However, unmetered secondary water use has resulted in an increase in overall water use. Studies indicate that metering all water and charging for use reduces over watering and waste. The research efforts by the state of Utah's Division of Water Resources as well as the experiences of pioneering water providers like Spanish Fork City and Grantsville Irrigation Company show that metering is not only possible, but also economically feasible.

The state of Utah's experiences with Weber Basin Water Conservancy District, WaterPro Incorporated, and Grantsville Irrigation Company have shown the possibilities that new water metering technologies will provide in the near future. While magnetic meters and other such meters provide expensive functionality in a secondary water environment, the testing of the fluidic-oscillation-type meter gives hope for an inexpensive alternative. New technologies such as fluidic-oscillation suggest that the development of an economical meter for secondary water applications is not a possibility but an eventuality.

The systems of Spanish Fork and Grantsville demonstrate that filtration sufficiently cleans secondary water in order to meter its use. If secondary water quality can be improved through filtration, standard potable water meters can be used for metering. Well-developed filtration technologies can meet the needs of a variety of secondary systems.

It is important to note that while secondary metering is possible, economic feasibility can only be determined by considering many factors. The analysis of water demand, future population growth, water quality, etc., will allow water providers to determine which approach to secondary water metering best suits their needs and will help them determine the cost-effectiveness of alternatives. Investigation into the economic viability for various secondary metering approaches will be discussed in a forthcoming companion paper.

END NOTES

¹ Amiad Filtration Systems, Oxnard, Calif.

² SmartMeter SM700, Severn Trent Services, Chesterfield, England.

³ Spectrum water meter, Metron-Farnier, Boulder, Colo.; Flostar water meter, Actaris US Liquid Measurement, Greenwood, South Carolina.

⁴ Mega EBS filter, Amiad Filtration Systems, Oxnard, Calif.

⁵ PMM® multi-jet meter, Sensus Metering Systems, Raleigh, North Carolina.

⁶ Model MVR Magnetic Drive Vertical Turbine Meter, Hersey Meters, Cleveland, North Carolina.

CHAPTER IV

METERING RESIDENTIAL IRRIGATION WATER: TECHNOLOGICAL
APPROACHES AND COST ESTIMATION***ABSTRACT**

An increasing number of secondary or dual water systems are taking steps to meter all residential connections. While metering encourages conservation and provides increased manageability, metered systems also face unique challenges principally related to the quality of the water. In order to use standard meters, filtration must clean secondary water to a level sufficient for meters to perform well. Increased operational expenses due to water treatment, meters, meter reading, and maintenance interfere with inexpensive water pricing methods generally used in secondary systems. Consequently, the question of metering ultimately hinges on economic feasibility for the majority of secondary water providers.

The purpose of this article is to outline the technologies presently available for secondary water metering applications. Approximate costs and design requirements of these technologies are identified, thereby allowing water suppliers to determine the economic feasibility of metering. In addition, other design precautions and considerations for implementing secondary metering are discussed.

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INTRODUCTION

As many water suppliers face growing demands, their ability to manage and efficiently use water is increasingly vital. Secondary or dual water systems have become a common method of decreasing demands on potable water supplies (Smith, 2008; Utah DWRe, 2004c; Okun, 1997); however, as described in a paper previously published by the authors, the lack of metering on these systems has actually led to an increase in overall water use (Richards et al, 2008). Although secondary systems do not typically meter water due to the inability of standard residential meters to pass debris found in untreated surface water or groundwater, several systems have used filtration or experimented with innovative meter designs to allow metering of secondary water as described in the same previously published article.

The purpose of this paper is to combine the experiences of these pioneering systems with the results of lab testing and in-depth research to help secondary water providers make decisions about metering. In deciding whether or not to meter, it is important for water providers to understand both the benefits and the drawbacks to metering, the types of filtration available, recommended meter types, and other design considerations as addressed by the authors.

Benefits to metering. In order for a secondary water system to justify metering, the benefits associated with metering must outweigh the costs of implementation. One of the greatest benefits of metering is the ability to manage water supplies. Water meters allow equitable billing and promote conservation and wise water use. This is true in systems where users pay a fixed fee for a secondary connection as well as in systems using water shares. As users become accountable for their water use in metered systems, they

typically become more aware of the water they use, thereby decreasing the total water demand. Depending on a system's water right, this conservation may create a surplus water supply allowing for the possible expansion of the current system, the ability to plan for future growth, or the option of selling excess resources to other entities. In a recent survey of Utah water system managers performed by the authors, over 90 percent of secondary system managers viewed the conservation of water as an important benefit to metering (Appendix B). Previous studies indicate a 10 percent to 40 percent reduction in potable water use when meters are installed (CSU, 2003; Bohanna, 1998; Kay, 1998; Bramfit et al, 1997). A 15 percent reduction in water use is considered typical for a potable system. Secondary or dual irrigation systems could expect a greater reduction in water use since outdoor water use has been found to be more elastic (demand is susceptible to reduction due to metering) than indoor water use (CSU, 2003). In a small sample of secondary connections at Wolf Creek Irrigation Company in Eden, Utah, average water use was reduced by 20 percent in the first two years of metering (Knobla, 2008). Other benefits such as leak detection were viewed as positive consequences of metering but are not as critical to secondary systems.

It is important to note that the aforementioned benefits to metering secondary water are not necessarily applicable to all systems. For example, a system with a more than adequate supply would gain little through metering if there is no opportunity to expand or sell conserved water resources. While the ability to charge users according to actual use is beneficial, it is questionable whether that benefit is worth the increased expense of metering. The major benefit to metering secondary water is in the conservation that metering instigates.

Hindrances to metering. Metering secondary water is, above all, a question of economic feasibility. Secondary water is intended to be a low-cost alternative to treated, potable supplies for outside irrigation. Since over 65 percent of residential water use in most western states is outdoor use (SNWA, 2007; Utah DWRe, 2000), secondary water provides users with a less expensive alternative to irrigate lawns and gardens while allowing municipalities and other water providers to conserve potable water. The question of metering in secondary systems can create controversy because of the related cost. Any cost increase due to metering secondary water corresponds to a water rate increase for the user, and excessive rate increases defeat the objective of providing less expensive water for outdoor use. This study addresses the costs of water meters, filtration, maintenance, and billing, offering secondary water providers the information necessary to determine if metering is economically feasible for their system.

A survey of Utah water providers shows that, aside from their concerns about the expense of metering, secondary water providers believe that current metering technologies are unable to function in a secondary water environment due to debris in the water. While many systems have unsuccessfully tested meters, and while most standard water meters are incapable of metering debris-filled water, several systems have found success by using various types of filtration to clean the water sufficiently to allow for metering. Additionally, several innovative meter designs have shown promise in passing debris without additional filtration. It is likely that the passing of debris through meters will not be a concern in the coming decade as metering technologies advance and meter manufacturers become increasingly aware of the demand for such a meter.

There are many other concerns that secondary water system owners face when considering metering, including the risks associated with meter warranties. Most meter manufacturers will not guarantee the internal, wetted mechanisms of meters used in a secondary system, even if the water is finely filtered. The conversion of and accessibility to existing connections poses a problem for many systems where meters would need to be installed in fenced or previously landscaped areas. Additionally, public support for metering is difficult to obtain in areas where secondary water has traditionally been billed using a fixed fee. Users typically view metering as a way to make them pay more for what they are already using.

Determining feasibility. In order to assess the practicality of metering secondary water, both benefits and costs need to be identified and compared. The benefits that a system receives from metering are system-specific and not easily quantified. For example, a system might reduce demand by 15 percent through metering. This would correspond to a specific amount of water that could be priced accordingly; however, the 15 percent decrease in water use might provide a system the extra capacity needed to avoid an expensive water allocation project. In such a case, the benefits of water conservation cannot be quantified simply by the value of the water saved. Furthermore, benefits such as leak detection and the ability to charge users according to actual water consumption must be assigned some face value in order to carry out a standard cost versus benefit analysis. Since each system will value these benefits differently, there is not one method of calculating benefits that is appropriate for all secondary systems.

The cost of metering is more easily quantified. Prices of physical appurtenances such as filters, meters, and meter reading devices as well as operation and maintenance costs

are readily obtained, given that the system requirements are known. The remainder of this article is intended to assist secondary water suppliers in selecting the secondary water metering technology best suited to their individual systems, thereby allowing them to calculate approximate costs of metering. These costs can then be weighed against the total benefit for a given system or broken down to estimate a feasible water rate structure associated with metering. All costs provided in this article are estimations and are given only as guidelines. Cost estimations are based on prices in the beginning of 2008.

SECONDARY WATER METERING TECHNOLOGIES

Centralized filtration. One technology used to facilitate secondary water metering is centralized filtration. Using this technique, all water is filtered to a degree that permits metering by standard water meters. Several systems have successfully implemented metering using a variety of centralized filter types. Spanish Fork City, Utah has been metering approximately 8,000 connections for six years. Their system has a capacity of 15,000 gallons per minute (gpm) using three 16-inch automatic self-cleaning filters.¹ They have experienced few problems using a multi-jet-type meter.² Santaquin City, Utah has used a less expensive centralized filter on their newly constructed secondary system. Two manual-flush filters³ are installed in parallel and are each rated at 1200 gpm. Santaquin also uses a multi-jet meter² for its secondary system. Levan Irrigation Company in central Utah has an even less sophisticated method of filtration. Water from mountain runoff and canals is diverted into a settling basin. The water then passes over a weir onto a simple screening structure. Most debris is filtered out before the water enters the pressurized system. While Levan Irrigation Company has purchased and installed

multi-jet meters² on about 260 residences, they are not yet in use. This secondary system is currently used only for farm irrigation where larger irrigation meters have been installed on about 70 connections.

The wide spectrum of centralized filtration technologies allows systems of all sizes to meter secondary water at a reasonable cost. Smaller systems, such as Santaquin or Levan, use affordable filtration and are able to operate and maintain these filters without significant maintenance costs. Spanish Fork City, on the other hand, has invested in a more expensive filtration system with an automatic cleaning mechanism. Due to the large flows required in their system, a manual flush type filter would be maintenance intensive. Figure 5 depicts the range of cost for filtration versus flow rate in gallons per

Figure 5 Centralized filtration cost estimation

minute. This cost information was obtained through communication with several filter manufacturers including Amiad Filtration Systems, Clemons Sales Corporation, Netafim, Orival Inc., and Tekleen Automatic Filters Inc. (Appendix C). Fully-automated filters tend to be in the upper end of the given range while manual flush filters are represented by the lower bound. While system pressures, water quality, and desired screen size all affect the total cost of filtration, these costs based on maximum design flow rate provide an adequate cost estimate to allow water providers to determine the feasibility of such a system.

One concern regarding centralized filtration is the potential for pipe scale to foul the meters. Typical secondary systems are only in use during summer irrigation months and are drained during the winter. Dissolved or very fine matter passing through the filter may build up on pipe walls and dry during winter months. When the system is repressurized, the scale may break off and either clog or jam meters. While this is a valid concern, none of the secondary systems currently using centralized filtration have reported such problems. Water sources that have high pH and alkalinity levels and also have significant hardness levels associated with carbonate compounds have greater potential to form pipe scale (MECC, 2008).

Individual connection filtration. Another filtration option is to install individual filters before the meter at each connection. Many smaller systems find it more convenient to install these small filters when retrofitting each connection with a meter than to make large system modifications to install a centralized filter. Grantsville Irrigation Company in Grantsville, Utah has successfully metered over 500 secondary connections using individual filters⁴ for about five years. These small filters are installed

before a combination of turbine meters⁵ and fluidic oscillation meters.⁶ Additionally, Wolf Creek Irrigation Company in Eden, Utah has been using individual connection filtration for over four years. Wolf Creek Irrigation Company serves 900 connections and has installed positive displacement, piston-type meters⁷ on all connections. Both systems have had few problems with the meters over the entire time of installation.

Individual filters range in price from \$20 to \$100 depending on flow rate and connection size. A typical 1-inch diameter plastic filter with a maximum flow of 30 gpm can be purchased for approximately \$60. Typically, the upfront cost of filtering individual connections will be greater than the cost of filtering the entire system at one centralized point (Miller, 2001).

While many systems find the small filter appealing due to the ease of installation and the added protection against possible pipe scale, others find the maintenance requirement of individual filters to be much too high. Depending on water quality, small filters must be flushed anywhere from once a week to once in an entire season. Systems using such filters typically assign maintenance responsibilities to individual users and then perform periodic filter checks to ensure proper maintenance. It appears that the effort and cost of such maintenance is unreasonable for larger systems, hence the option to maintain one or two filters at centralized locations is preferable. It is largely for this reason that Spanish Fork City opted to use a centralized unit as opposed to individual connection filters.

The transfer of maintenance responsibilities from the water company to the user presents several concerns. First, typical small filters are flushed through a hose bib on the filter body. Since the filter is placed before the meter, many water suppliers are

concerned that users will bypass the meter using the filter's flush design, thereby stealing water. Grantsville Irrigation Company has found that a few users have tired of flushing their filters and have completely removed the filter elements, thereby allowing unfiltered water to pass on through the system. This action can either clog or damage the interior of the water meter. Grantsville views this as an act of vandalism and holds the user responsible for damages.

Metering technologies. With an adequate amount of filtration, most typical water meters will function in a secondary water system. Given that secondary water meters face a higher probability of passing debris than those in a potable system, even when filtration is present, meters unaffected by debris are highly recommended for use in secondary systems. Newer designs such as single-jet, multi-jet, and turbine meters are less likely to be jammed or worn down by debris than typical positive displacement models (Allen, 2008). Typical 2008 prices for meters according to type and size are given in Table 2.

Most meter manufacturers will not uphold a warranty on the wetted parts of a meter installed in a secondary system, whether the water is filtered or not. The lack of a

Table 2 Water meter cost estimations

Meter Type	Diameter in.	Price Range—\$	Typical Flow Range—gpm
Multijet	$5/8 \times 3/4$	40–60	$1/4$ –20
	$3/4$	45–70	$1/2$ –30
	1	100–115	$3/4$ –50
Single jet	$5/8 \times 3/4$	85–170	$1/4$ –20
	$3/4$	105–165	$1/2$ –30
	1	180–320	$3/4$ –50
Fluidic oscillation	$5/8 \times 3/4$	100–110	1–20
	$3/4$	100–110	2–30

warranty has deterred some secondary systems from installing meters, even when filtration was already in place. It is important to note that only the wetted parts of a meter are affected by debris in secondary water. All other parts of the meter, including the register and body, will likely be under warranty. Secondary systems currently metering their water have faced little or no opposition to the replacement of defaulting meter parts under warranty, and since these systems have adequate water filtration, few if any meters have failed due to debris. Manufacturer policies vary when it comes to warranties for secondary meters, however, so it is important to understand these policies before any purchase is made.

Research has also been performed on the possibility of using standard water meters without any type of filtration. Almost without exception, a standard water meter without filtration will be the least expensive solution; however, questions remain as to whether these meters can reliably function in specific secondary systems. While there are meters that handle debris well, no water meter has been proven to function over extended periods of time in a secondary system.

Testing performed at the Utah Water Research Laboratory in Logan, UT, on fluidic-oscillators⁶ and single-jet meters⁸ demonstrated the ability of both meter types to pass particulate matter while maintaining meter accuracy (Allen, 2008). At a particulate concentration of 150 parts per million (PPM), single-jet meters recorded an average of 99.29 percent of total flow while fluidic oscillators recorded 99.53 percent (Table 3). Both of these flow percentages fall within the AWWA accuracy standards for new meters (AWWA, 2005; AWWA, 2002). At a particulate concentration of 7500 PPM, a concentration that would be highly unlikely in any typical secondary system, both types

Table 3 Dirty Water Accuracy at 20 gpm (Adapted from Allen, 2008)

Meter Number	Meter Type	Size—in.	Clean Water—%	Water With 150 mg/L—%	Water With 7,500 mg/L—%	Water With 22,500 mg/L—%
1	Fluidic oscillator	5/8	100.16	99.70	99.53	97.13†
2	Fluidic oscillator	5/8	99.80	99.56	98.85	97.18†
3	Fluidic oscillator	5/8	99.08	98.17†	98.29†	96.78†
4	Fluidic oscillator	3/4	99.77	98.95	95.8†	80.25†
5	Fluidic oscillator	3/4	99.11	100.13	97.00†	53.04†
6	Fluidic oscillator	3/4	99.50	100.65	98.05†	78.75†
7	Single jet	3/4	99.49	101.26	99.61	94.64†
8	Single jet	3/4	98.67	99.93	100.05	97.04†
9	Single jet	3/4	99.60	99.52	98.21†	100.00
10	Single jet	1	98.66	97.61†	98.67	98.05†
11	Single jet	1	98.96	96.91†	95.23†	94.82†
12	Single jet	1	96.96†	100.52	97.89†	0.00†

†Meter is not compliant with AWWA accuracy standards.

of meters failed to meet AWWA standards, but all meters still registered above 95 percent of total flow. This testing demonstrates that both single-jet and fluidic oscillator meters can function in debris-filled water; however, it does not determine if these meters will function over an extended period of time in the field. The addition of organics such as algae or moss, possible pressure spikes, harsh environmental conditions, and the effects of draining and repressurizing the system every season all contribute to the degradation of a meter.

Many secondary systems in Utah have experimented with various possible meters. Some systems, including the Weber Basin Water Conservancy District, Grantsville Irrigation Company, and WaterPro Inc. (Draper, UT), have participated in a study on fluidic-oscillation-type meters⁶ led by the Utah Division of Water Resources. A sample of these meters that were tested for accuracy registered between 95 and 101 percent of accuracy on flows above 2 gallons per minute (Allen, 2008). The Division of Water Resources' study revealed that the fluidic-oscillation meter is unaffected by typical debris found in secondary systems; however, it also revealed that the meter's electronic

components are prone to failure (Stephens, 2007). The manufacturer of the fluidic-oscillator has since taken steps to ensure the protection of meter electronics (Searle, 2007). Weber Basin Water Conservancy District is currently planning to meter all new developments using the fluidic-oscillation meter (McKnight, 2008). Other secondary systems such as Saratoga Springs City, UT, have implemented their own studies into several types of meters. Despite these efforts, no one meter type has been proven adequate to meter unfiltered secondary water over its entire lifespan. As these studies progress and larger-scale installations occur, the reliability of these meter types will be more apparent.

Depending on water quality, certain systems may be able to meter without filtration. The testing of a large sample of meters over the course of several seasons will validate any decisions regarding meter selection.

SELECTING AN APPROACH

Essentially, there are four basic alternatives to consider when determining an approach to secondary water metering: 1) Install a centralized filter station, 2) Install individual filters at each user connection, 3) Install currently available meters with no filtration, 4) Do nothing and wait for metering technologies to advance. Table 4 outlines the basic advantages and disadvantages to each approach. The preferred alternative is the installation of a centralized filtration system. A centralized filter along with basic water meters can yield all of the water management and conservation benefits previously discussed. Individual filters can provide the same benefits; however, it is typically more expensive to purchase individual filters for each connection than to install a centralized

Table 4 Technology comparison summary

	Centralized Filter Station	Filters for Individual Connections	Metering without Filtration	Wait for Technology to Advance
Benefits	<ul style="list-style-type: none"> ▪ Large variety of filtration types for all sizes of systems ▪ Typically a cost-effective solution ▪ Limited maintenance 	<ul style="list-style-type: none"> ▪ Can be installed at same time as the meter ▪ Installed directly in front of meter providing added protection 	<ul style="list-style-type: none"> ▪ Least expensive way to meter ▪ Very limited maintenance provided that meters are not affected by debris 	<ul style="list-style-type: none"> ▪ Least expensive alternative ▪ No additional maintenance required ▪ New meter designs possible within the next decade
Disadvantages	<ul style="list-style-type: none"> ▪ Added cost of filtration ▪ Large system modifications required ▪ Concern that pipe scale will dry and break off while the system is drained and potentially foul meters 	<ul style="list-style-type: none"> ▪ Added cost of filtration ▪ Typically more expensive than centralized filter ▪ Difficult to maintain filters at every system connection ▪ Concern that users will steal water through filter flushing mechanism 	<ul style="list-style-type: none"> ▪ Meter testing required for several seasons before widespread installation ▪ Shorter meter life due to suspended debris ▪ No economical meter has been proven to function over long periods of time in any secondary system 	<ul style="list-style-type: none"> ▪ Lack of water management capabilities ▪ Lack of user accountability and conservation incentives
Comments and Recommendations	<ul style="list-style-type: none"> ▪ Recommended alternative at the present time ▪ When water is sufficiently filtered, any type of water meter can be used ▪ Centralized filtration and standard meters can cost less than the purchase of a durable water meter that can handle debris in some cases 	<ul style="list-style-type: none"> ▪ Not encouraged since it is more expensive than a centralized filtration unit for most systems ▪ Exceptions would be for small systems that cannot make large-scale system alterations, are concerned about the possibility of pipe scale fouling meters, or provide large flows to individual users (such as farmers) which would increase the price per connection of a centralized filter 	<ul style="list-style-type: none"> ▪ Not encouraged since no known system has found a proven meter ▪ The purchase, installation, and observation of several meter types is recommended for all systems who have interest in metering ▪ Certain systems with very clean source water, such as wells or recycled wastewater, may find widespread metering without filtration to be feasible 	<ul style="list-style-type: none"> ▪ According to current conservation ethic, this alternative is the least desirable ▪ When considering economics, many smaller systems may find other alternatives to be too costly ▪ Small systems such as these can make efforts to install test meters or wait for metering technologies to advance and the costs of these technologies to decrease

filter. Exceptions may include systems serving farms or other agricultural users who demand a higher flow rate than an average residential user. The increase in peak flow increases the cost per connection for a centralized filter unit. If the cost of centralized filtration (as determined from Figure 5) divided by the number of connections served is greater than the installation cost of an individual filter then individual connection filters should be considered.

Water quality and filtration. According to a major filter manufacturer⁹, the recommended filtration level for a secondary water system installing meters is 80 microns. The systems currently using filtration, however, have had success using a range of filtration levels from the recommended 80 microns up to 500 microns. The Santaquin City pressurized irrigation system uses a pressurized screen filter with 3/32-in (about 2300-micron) openings and has experienced zero meter failures in the first two years of service.

While filtration effectively cleans water in order to protect meters, it also has limitations. In systems with large concentrations of suspended solids, screen filters tend to lose efficiency. A concentration of 80 PPM of total suspended solids (TSS) is considered the maximum concentration at which a screen filter can effectively operate (Maher, 2008). This limit does vary with selection of micron-rating and the particle size distribution of the debris. Many filter manufacturers will perform water quality tests before sizing a filter for large-scale projects. In systems with very high TSS concentrations, alternative types of filters or preliminary treatment processes can be considered.

Metering without filtration. Water quality is also an important consideration for systems investigating the use of meters without filtration. The quality of secondary water is difficult to determine since it is often subject to seasonal changes such as high sediment content during peak spring flows and fluctuations in the level of organic content throughout the year. While no standard classification system exists for secondary water, the main concerns are the amount of sands or silts and organics in the water. Sands and silts can be very damaging to water meters if water is unfiltered. Jet-type, turbine, and oscillation meters typically will not clog due to sand particulates, but meter interiors are worn down and lose accuracy over time due to the passing of sand and grit. Sand and grit can also foul the bearings of the metering mechanism. Positive displacement meters have a higher tendency to malfunction due to suspended sediments in the water. Organic debris can include leaves, algae, snails, fish, etc. This type of debris tends to create a higher potential for clogging in most types of meters. In a system with any substantial amount of debris, filtration should be viewed as a necessity.

The clogging potential of secondary water can be based on classifications developed for drip irrigation systems. Drip emitters have orifice openings ranging from 0.02 to 0.05 inches (about 500 to 1250 microns), which is smaller than the typical smallest orifice of any standard water meter (New & Roberts, 2008). For comparison, typical multi-jet-type meters have screens with 0.05- to 0.10-inch openings (1250 to 2500 microns), fluidic oscillation meters have a smallest orifice size of about 0.19 inches (4800 microns), and single-jet meters often do not have any straining mechanisms at all. In drip systems, TSS concentrations of less than 50 PPM are considered a minor clogging hazard, 50-100 PPM are viewed as a moderate hazard, and greater than 100 PPM are a severe hazard (Bucks et

al, 1979). While meters will pass larger debris than a drip system, these guidelines can be useful in determining the feasibility of using meters without filtration, especially for meters with smaller orifices such as the multi-jets. It is important to note that other physical, chemical, and biological factors can cause the plugging of small orifices and should be investigated before installation of meters without filtration.

Systems that are financially unable to filter can either experiment with meters as previously described or wait for advancing metering technologies to provide a low-cost meter that can pass debris. While the fluidic-oscillator flow meter is susceptible to electronic failure, it is a good example of recent technological advances that show promise for the future of secondary water metering. At least one major meter manufacturer¹⁰ in the United States is making efforts to develop a residential water meter with no moving parts (Casillas, 2008). As magnetic and ultrasonic metering technologies advance, manufacturers will likely use those technologies to develop meters that are more suitable, economically and otherwise, for secondary systems.

ECONOMIC FEASIBILITY

Due to the diversity of secondary system designs as well as the number of possible approaches to metering, no single method can correctly determine the feasibility of metering for every system. However, using the information provided in this paper along with accurate system parameters such as design flow rate, number of connections, and general water quality, the approximate initial cost of metering can be determined. This will allow secondary water providers to make informed decisions concerning whether or not to pursue metering on a large scale.

Initial cost per connection. One logical approach a system owner may consider is to assess the initial cost of metering on a per connection basis. This estimate can be divided into a monthly rate increase per connection over the life of the project according to Equation 1:

$$\text{Monthly Rate Increase per Connection} \approx \frac{F + M + I_m + I_l + MR}{12L} + OM \quad (1)$$

where F is the cost of filtration per connection, which is the cost associated with a design flow rate (as determined in Figure 5) divided by the number of connections for a centralized filter, the cost of an individual filter (around \$60), or zero if no filtration is to be used. M is the cost of the desired meter as determined from Table 2. I_m is the cost of installation materials such as pipe, meter box, and valves, which would typically be between \$50 and \$100. I_l is the cost of installation labor for one connection. MR is the initial cost of the automatic meter reading device varying from \$65 to \$150 depending on the type of device (Koch, 2008). This term can be eliminated if no automatic device is to be used. For systems that use manual or drive-by reading systems, this monthly meter reading cost should be added into OM , which is the monthly operation and maintenance costs including meter reading and billing. L is the expected life of the meter and filter in years, varying from 10 to 20 years.

This equation does not take into consideration any meter or filter replacement costs, nor does it consider the economic impacts of inflation or interest rates. The equation allows secondary water providers a simple method by which to evaluate the approximate cost of metering to the individual user. A more accurate estimate of monthly rate increase per connection can be found by considering interest rates. Using this approach,

the summation of F , M , I_m , I_l , and MR is multiplied by a Capital Recovery Factor (which is a variable of the interest rate and L , the expected life of the meter and filter in years). This product is then divided by 12 and added to OM , the estimated monthly operation and maintenance costs due to metering.

Other economic considerations. As stated previously, no single method used to determine the economic feasibility of metering will be effective in all cases due to the diversity of secondary system designs. Some specific insights, however, may be useful. For example, there is a great difference between an existing secondary system and the proposed construction of a secondary system. While the installation of meters and filtration on an existing system is much less expensive than the construction of a new system, it is also true that the installation of meters and filtration is less expensive if done with the construction of the system rather than retrofitting connections at a later date. Every proposed secondary system should consider the installation of meters prior to construction of the system.

For existing systems, an analysis of current and future demands as well as source capacity is crucial in determining the overall benefit of metering. If a system has ample water supply to meet build-out demands even without conservation efforts, one could argue that metering would be a waste of effort and funds unless the surplus water could be sold or used in other locations experiencing water shortages. Conversely, if a system is unable to meet future demands and if metering would reduce demand sufficiently to make up the difference, the installation of meters may be a welcome alternative to an expensive water allocation or importation project.

The maintenance policies and available staff in individual systems will greatly impact the feasibility of metering as well. Very large systems may need to create an entire department to deal with meter and filter maintenance. The type of meter reading is also an important operation and maintenance issue. Municipalities already using automatic meter reading devices such as drive-by or radio-read on potable water meters would experience relatively little increase in reading costs due to the addition of secondary meters. Conversely, systems that manually read meters or that do not operate jointly with potable water suppliers may have substantial cost increases due to meter reading.

DESIGN PRECAUTIONS

Meter failure is the primary concern when considering the widespread installation of metering on a secondary system. This paper has focused primarily on fouling and clogging due to debris, but it is also important to be aware of two other hazards to meters in secondary systems. First, meters can sustain considerable damage when residual water freezes after a system has been drained. Because of this possibility, systems currently metering have taken the precaution to sufficiently drain meters at the end of the irrigation season. Additional ways to minimize freezing problems include slanting lateral water lines down towards the main line and installing automatic freeze-protection drains on both sides of the meter to allow for better meter drainage.

The other potential hazard for water meters is due to pressure spikes in the system, especially as the system is repressurized at the beginning of the irrigation season. High pressures can burst measuring chambers or damage internal metering mechanisms. If a system is repressurized in a slow and orderly manner, however, pressure spikes should be minimal.

CONCLUSIONS

As water demands increase, many secondary water suppliers are looking to metering as a possible way to curb overuse and efficiently manage their water supplies. The use of water meters in debris-filled secondary water is, however, questionable since debris tends to foul the moving parts of mechanical meters. Due to the added expense of meter installation and maintenance, the practice will also lead to increased rates for secondary water users. The four main metering options for secondary water systems are: 1) use centralized filtration to sufficiently clean water for water meters before it enters a system, 2) use individual filters at each connection before the meter, 3) experiment with innovative meter technologies that are debris-tolerant, 4) wait for current metering technologies to advance.

For most systems, installing a centralized filter and standard residential meters will be the most cost-effective and reliable approach. Certain smaller systems, such as those serving a large agricultural demand in addition to the residential demand, may find individual filters to be more economical than a large, centralized filter. For those not wanting to use filtration, several types of meters show promise in passing debris-filled water such as single-jet and fluidic-oscillation meters; however, these meters have not been sufficiently proven in the field and should not be widely installed without preliminary testing. For those who lack financial resources, it is very possible that metering technologies will advance in coming years and produce a more economical meter that can pass debris without filtration.

In order to correctly analyze the economic feasibility of metering for a secondary system, an analysis of a system's demand, supply, water quality, etc., needs to be

performed. An approximate cost estimate can be determined using the approach summarized in the paper and can provide a basis for determining the economic feasibility of metering. When considering metering of a secondary system, the experience of systems currently metering as well as proper design guidance should be utilized. These resources will reduce potential problems and ensure the proper approach to metering.

END NOTES

¹Mega EBS Filter (80-micron), Amiad Filtration Systems, Oxnard, California.

²PMM® Multi-jet Meter, Sensus Metering Systems, Raleigh, North Carolina.

³Pressure Fine Filter (3/32-in), Clemons Sales Corporation, Boise, Idaho.

⁴1-in Super Plastic Filter, Amiad Filtration Systems, Oxnard, California.

⁵MVR Magnetic Drive Vertical Turbine Meter, Hersey Meters, Cleveland, North Carolina.

⁶SmartMeter SM700, Severn Trent Services, Chesterfield, England.

⁷C700 Positive Displacement Meter, Elster AMCO Water, Inc., Ocala, Florida.

⁸Flostar Single Jet Meter, Actaris US Liquid Measurement, Greenwood, South Carolina.

⁹Amiad Filtration Systems, Oxnard, California.

¹⁰Sensus Metering Systems, Raleigh, North Carolina.

CHAPTER V

SUMMARY AND CONCLUSIONS

With rapid growth and limited water supplies, many water systems throughout the United States and in particular those in western states are aware of the need for water conservation. Supplying secondary water is an approach that reduces demand on potable water and allows for more connections. However, unmetered secondary water use has resulted in an increase in overall water use. Studies indicate that metering all water and charging for use reduces over-watering and waste. The research efforts by the state of Utah's Division of Water Resources as well as the experiences of pioneering water providers show that metering is not only possible, but also economically feasible. The four main metering options for secondary water systems are: 1) use centralized filtration to sufficiently clean water for water meters before it enters a system, 2) use individual filters at each connection before the meter, 3) experiment with innovative meter technologies that are debris-tolerant, 4) wait for current metering technologies to advance.

The state of Utah's experiences with Weber Basin Water Conservancy District, WaterPro Incorporated, and Grantsville Irrigation Company have shown the possibilities that new water metering technologies will provide in the near future. While magnetic meters and other such meters provide expensive functionality in a secondary water environment, the testing of the fluidic-oscillation-type meter gives hope for an inexpensive alternative. New technologies such as fluidic-oscillation suggest that the development of an economical meter for secondary water applications is not a possibility but an eventuality.

The systems of Spanish Fork, Utah and Grantsville, Utah demonstrate that filtration sufficiently cleans secondary water in order to meter its use. If secondary water quality can be improved through filtration, standard potable water meters can be used for metering. Well-developed filtration technologies can meet the needs of a variety of secondary systems. For most systems, installing a centralized filter and standard residential meters will be the most cost-effective and reliable approach at the present time.

For those not wanting to use filtration, several types of meters show promise in passing debris-filled water such as single-jet and fluidic-oscillation meters; however, these meters have not been sufficiently proven in the field and should not be widely installed without preliminary testing. For those who lack financial resources, it is very possible that metering technologies will advance in coming years and produce a more economical meter that can pass debris without filtration.

It is important to note that while secondary metering is possible, the economic feasibility of each approach can only be determined by considering many factors. The analysis of water demand, future population growth, water quality, etc., will allow water providers to determine which approach to secondary water metering best suits their needs and will help them determine the cost-effectiveness of alternatives. Additionally, systems considering the use of secondary water meters should solicit the experience of systems currently metering. This design resource will reduce potential problems and ensure the proper approach to metering.

CHAPTER VI

FUTURE RESEARCH

The research presented in this thesis attempts to summarize the use of filtration as a means to meter secondary water, considering both the hydraulic and economic feasibility of such a project. Many possible meters to be used in secondary systems without filtration are also discussed but without definitive conclusions. In most cases, this is due to a lack of field testing over an extended period of time.

The author recommends that testing be done on several types of meters including the fluidic-oscillation-type meter, single-jet meter, turbine meter, and multi-jet meter. In order to obtain an accurate representation of meter performance, multiple meters of each model should be installed over the course of several irrigation seasons. Due to large variations in secondary water quality, meters should be installed in several secondary systems using a variety of water sources. Since it is difficult to recreate the conditions and environment that secondary water meters are exposed to, the author recommends that all testing be performed in actual secondary systems rather than in laboratory simulations. It would also be beneficial to test the endurance of automatic meter reading (AMR) devices in such an environment. The functionality of AMR devices, which could be exposed to harsh conditions when installed in a secondary system, is critical to the success of a metered system.

As previously noted, water metering technologies are rapidly advancing. As meter manufacturers are made aware of the demand for an inexpensive and debris-tolerant meter, the problem of metering secondary water may very well be resolved. A continual

survey of available meter types and models will ensure that suitable meters be identified and tested accordingly.

In addition to continued research of possible debris-tolerant meters, other studies could address concerns faced by systems considering filtration. The major concern with the use of a centralized filter is that scale will form on pipe walls, harden when the system is drained for the winter, and then break off and foul meters when the system is repressurized in the spring. Since no systems that are currently using centralized filtration have reported problems with scale, it would be useful to determine whether or not this is a genuine concern. Such a study would include in-depth analysis of biological and chemical water quality characteristics, filtration levels, scale formation processes, and meter capabilities. Other impacts of the annual draining and repressurization of secondary systems on meters, filters, and other system components could also be investigated.

Additionally, the creation of a secondary water quality classification system would be beneficial for systems considering the installation of filtration and/or meters. Water quality is an important factor in designing filter screen sizes and micron-ratings in order to pass a design flow for centralized filtration. Meters could also be classified according to the type of water they are capable of metering. Such a classification system would most likely consider both the concentration and particle size distribution of inorganic and organic debris in the water. Given that pipe scale formation is also a concern, the chemical makeup of the water should also be considered. Secondary water quality classification is touched on in the preceding chapters of this thesis, but was not fully developed due to its complexity. It is important to realize that the water quality of any

secondary system will vary according to its source, time of year, weather events, etc. A classification system should address this variance with time.

Finally, while it is justifiable to say that the metering of secondary water will reduce water consumption by increasing user accountability, there are also other technologies and management practices that could effectively curb the use of outdoor water in Utah. Evapotranspiration or soil moisture sensors can help residential users to water responsibly if they are used and installed properly. The creation and enforcement of more rigorous watering restrictions can also reduce water use substantially. Rebate and educational programs to encourage the conversion of turf grass to xeriscaping could also be considered in lieu of metering.

Each of these alternatives to metering offers a different level of water savings at a different price. Research should be done to identify the water savings potential and economic feasibility of each alternative to metering.

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APPENDICES

APPENDIX A: RELEVANT PHOTOGRAPHS

Grantsville Irrigation Company.

Figure A1 Mineral buildup on meter interior. This nutating-disc-type water meter from Grantsville's pressurized irrigation system and is a good example of the buildup that can occur due to secondary water.

Figure A2 Standard drain used by Grantsville Irrigation Co. These drains are installed on both sides of the meter and automatically release water when pressures are low.

Figure A3 Grantsville Reservoir. Grantsville Irrigation Company stores the runoff of several mountain streams in this reservoir. This is their only source of irrigation water.

Figure A4 Metered connection at Grantsville Irrigation Company. Grantsville's standard connection consists of a meter preceded by a small filter. Drains are also installed but are not visible in the photo.

Figure A5 Individual filter screen. Grantsville Irrigation Company has used a variety of screen types in its individual filters including disc- and perforated-type mediums. They have had the most success with the mesh screen as pictured above.

Levan Irrigation Company.

Figure A6 Open channel screening structure. Levan Irrigation Company reduces debris in their secondary system by sending water through a settling basin and then screens its water as it passes over a cipoletti weir. Maintenance of this structure includes regular cleaning of the screen as well as flushing of the settling basin.

Figure A7 Poorly designed screening structure. The under sizing of this settling basin causes higher velocities than desired for settling debris as can be seen by the turbulent water surface prior to the screening structure. Additionally, a low weir height allows high velocity flows to splash over the screen rather than passing through it.

Figure A8 Metered connection at Levan Irrigation Company. Levan's secondary water connections consist simply of a meter in a metal utility box.

Santaquin City Pressurized Irrigation System.

Figure A9 Santaquin City's regulating pond. This pond regulates the pressure in Santaquin's secondary water system. The pond is suspect to algae blooms as seen in the picture which can cause meter failure if left in the system.

Figure A10 Manual-flush filters in Santaquin City. Santaquin City Pressurized Irrigation water is filtered by one of two screen filters. These filters have to be manually flushed and maintained.

Figure A11 Flushing the filter. A member of Santaquin City's maintenance staff is shown above flushing one of the screen filters. If the filters are not flushed regularly, debris will clog up the filter screen causing a downstream pressure drop.

Figure A12 Metered connection at Santaquin City Pressurized Irrigation System. Santaquin's secondary water connections consist simply of a meter in a plastic valve box.

Spanish Fork City Pressurized Irrigation System.

Figure A13 Spanish Fork City's secondary water reservoir. This reservoir stores up to 22 million gallons of secondary water.

Figure A14 Spanish Fork's pump and filter station. This station is housed below the storage reservoir. The screen filter has an automatic self-cleaning mechanism which decreases the required maintenance.

Figure A15 Filter screen. The self-cleaning filters pass water through a mesh screen which is periodically sucked clean by a rotating vacuum. Pictured above is a replacement screen rated at 130 microns.

Figure A16 Metered connection at Spanish Fork City. Since water is filtered at a centralized unit, a typical connection in the Spanish Fork Pressurized Irrigation System consists of simply a meter, meter reading device, and control valves.

Utah Division of Water Resources' SmartMeter Study

Figure A17 Secondary system extreme conditions. In order for a meter to properly function, it must be durable enough to experience a wide spectrum of environmental extremes. These SmartMeters installed in the Weber Basin Water Conservancy District exhibit some of these harsh conditions.

Figure A18 SmartMeter with cracked chamber. This Severn-Trent SmartMeter has a cracked measurement chamber (probably due to freezing or a pressure spike) which is causing it to leak. Despite the leak and submersion, the meter is still functioning.

Figure A19 Interior view of SmartMeter. The measurement chamber of a SmartMeter is constructed of a very durable plastic. When this plastic chamber cracks, water can leak into the outer brass chamber which often causes meter electronics to fail.

Wolf Creek Irrigation Company.

Figure A20 Metered connection at Wolf Creek Irrigation Company. Wolf Creek Irrigation Company uses a standard piston-type meter in its system. This meter is protected by a small filter installed before the meter at each individual connection.

Figure A21 Diversion structure in Eden, Utah. Wolf Creek's secondary water source is a mountain creek above the town. Water is diverted from the creek to a storage reservoir prior to entering the system.

Figure A22 Service area of Wolf Creek Irrigation Company. Pictured above are some of the homes served by Wolf Creek. The system serves a portion of Eden, Utah, a town near Pineview Reservoir.

APPENDIX B: UTAH WATER SYSTEMS SURVEY RESULTS

A survey of municipalities, water conservation districts, irrigation companies, and other water systems in Utah was performed by the author during Summer 2008. This survey asked questions about secondary water metering and secondary systems in general. Since all of the systems participating in the survey were not secondary water providers, the survey was presented in a way that sorted each system into one of three categories: pressurized irrigation systems (secondary water systems), potable or drinking water systems, and open channel irrigation systems. Each of these categories was given a different form of the survey.

Several hundred water systems throughout the state were contacted by phone and invited to participate in the survey by email. Emphasis was placed on contacting secondary water providers since the study was specifically concerned with secondary water metering, but all types of systems were contacted. About 100 systems provided email addresses in order to participate. Of these participants, 30 secondary water systems, 14 potable water systems, and 6 open channel irrigation companies responded to the survey.

The names of these systems and a few system details such as location and number of users are provided in the following. Additionally, the compiled responses to the survey questions are summarized. The survey was useful in identifying systems that had interest or experience with secondary water metering as well as determining the current attitudes towards metering and water conservation.

List of Respondents (System Name, Location, Number of Users)

Pressurized Irrigation Systems

1. Saint George City Pressurized Irrigation; Saint George, UT; 500 users
2. Saratoga Springs City; Saratoga Springs, UT; 4000 users
3. Price River Distribution System; Price, UT; 500 users
4. Bountiful Irrigation; Bountiful, UT; 10000 users
5. Weber Basin Water Conservancy District; Layton, UT; 120000 users
6. Draper Irrigation Company; Draper, UT; 1956 users
7. 4800 West Water Users Association; West Valley, UT; 30 users
8. Home and Garden Irrigation Company; Davis County, UT; 100 users
9. Hyrum City Pressurized Irrigation; Hyrum, UT; 1790 users
10. Huntsville Waterworks Corp.; Huntsville, UT; 200 users
11. Benchland Water District; Kaysville, UT; 5000 users
12. Cub River Irrigation Company; Preston, ID; 100 users
13. Hyrum Irrigation Company; Hyrum, UT; unknown
14. Kays Creek Irrigation Company; Layton, UT; 1850 users
15. Riverton City Secondary Water System; Riverton, UT; 8600 users
16. Pineview Water System; Ogden, UT; 23000 users
17. First South Hyde Park Water Pipeline Company; Hyde Park, UT; 34 users
18. Line Creek Irrigation Company; Morgan, UT; 84 users
19. WaterPro Inc.; Draper, UT; 2000 users
20. Cedar Hills City Pressurized Irrigation; Cedar Hills, UT; 2200 users
21. Roy Water Conservancy Subdistrict; Riverdale, UT; 9600 users

22. South Jordan City; South Jordan, UT; 3200 users
23. Heber City; Heber, UT; 1000 users
24. Lakeview Water Corporation; Huntsville, UT; 110 users
25. Hillcrest Water Users Inc.; Perry, UT; 30 users
26. South Davis County Water Improvement District; Bountiful, UT; 1938 users
27. Central Utah Water Conservancy District; Orem, UT; wholesale provider
28. Wolf Creek Water Company; Eden, UT; 741 users
29. Grantsville Irrigation Company; Grantsville, UT; 1400 users
30. Washington City; Washington, UT; 200 users

Potable Water Systems

1. Centerville City; Centerville, UT; 4500 users
2. Mountain Green Water System; Morgan, UT; 19 users
3. Layton City; Layton, UT; 17500 users
4. Sandy City; Sandy, UT; 27900 users
5. Kearns Improvement District; Kearns, UT; 13200 users
6. Riverdale City; Riverdale, UT; 2288 users
7. Bona Vista Water District; Ogden, UT; 6200 users
8. South Salt Lake City; South Salt Lake City, UT; 18000 users
9. Murray City; Murray, UT; 9825 users
10. Park West Water Company; Cedar City, UT; 45 users
11. Herriman City; Herriman, UT; 4928 users
12. Granger-Hunter Improvement District; West Valley, UT; 106000 users

13. Jordan Valley Water Conservation District; West Jordan, UT; unknown

14. Eagle Mountain City; Eagle Mountain, UT; 20000 users

Open Channel Irrigation Systems

1. Delta City; Delta, UT; 50 users

2. Western Irrigation Company; Ogden, UT; 350 users

3. North Jordan Irrigation Company; Taylorsville, UT; 350 users

4. Price City; Price, UT; 3338 users

5. Brooklyn Canal Company; Monroe, UT; 135 users

6. Box Elder Creek Water Users Association; Brigham City, UT; unknown

Survey Results: Pressurized Irrigation or Secondary Water Systems

Which best describes water pricing methods used in your system?

Fixed Yearly or monthly fee	60%
Tiered pricing rates based on actual water use	13%
Shares of water purchased for water right	27%
Other	0%

Is there opportunity to expand your existing system in order to serve more people?

Yes	63%
No	37%

What is your water source? If supplied by multiple sources, check all that apply.

Well	47%
Spring	20%
Runoff	60%
Canal	57%
Other	20%

In what ways is water quality in your system improved? Check all that apply.

Filtration	23%
Screening	50%
Settling ponds	47%
Nothing - water is delivered as is	50%
Other	3%

The level of organic debris (plants, moss, algae, fish, etc.) in the water is:

None	7%
Low	48%
Medium	38%
High	7%

The level of inorganic debris (sand, silt, grit, etc.) in the water is:

None	3%
Low	55%
Medium	34%
High	7%

Are individual water connections metered in your secondary system?

Yes - all connections are metered	10%
Yes - a portion of connections are metered	33%
No - none of the connections are metered	57%

Has your system ever experimented with or researched the possibility of metering secondary water connections?

Yes	73%
No	27%

How likely is it that the State of Utah will enact and enforce laws or regulations that would make metering all water use mandatory?

Very likely	17%
Likely	14%
Indifferent	24%
Not likely	45%
No chance	0%

If metering is feasible in your secondary system, would your system be likely to implement universal metering?

Yes	24%
Maybe	28%
Probably Not	14%
No	21%
N/A - currently metering	14%

If state government agencies offered incentives (such as low-interest loans or rebates) to secondary systems who install meters, would your system be interested in implementing universal metering?

Yes	14%
Maybe	43%
Probably Not	14%
No	14%
N/A - currently metering	14%

How important of an issue is secondary water metering to your secondary water system?

Very important	21%
Important	34%
Indifferent	10%
Not important	21%
Other	14%

Do you have any other comments?

Saint George City: Secondary water systems are very important and help us to conserve water. As new developments are being built, the City gives incentives and I believe now requires developers to install secondary pipes for if not currently present, future secondary systems for all outdoor home use.

Huntsville Waterworks Corp: Our system has a holding pond that is in constant overflow. There is no way of saving the water for later....it is used or overflows.

Benchland Water District: cost and manpower and quality of the water are the issues

Kays Creek Irrigation Company: Money is a big part of this

Pineview Water System: In order to implement metering we would have to change our entire system of accounting and billing. It would effectively double the cost of our water.

Roy Water: In spite of the fact it doesn't seem to make economic sense we are willing to support any study and continue to demo new technologies

Hillcrest WUA: We have metering when the water comes out of the canal into our system. We are allowed so many acre feet per year, and we have to adjust our usage so that this amount is not exceeded.

CUWCD: I have not answered questions 9, 14, 15, & 16 because we wholesale only. However, these issues are of concern to the District and we support development and implementation of technology to account for the limited supply of water.

Wolf Creek Water Co: The State should actively pursue the metering of irrigation, making it a statewide priority. We cannot continue to treat our water resources as an endless supply - it will become as valuable to our dry climate as oil is to our nation. If we want to plan for continued growth we must conserve.

Grantsville Irrigation Co: I think all water should be metered

Benefits of Metering

■ Not important ■ Indifferent ■ Important ■ Very important ■ N/A

Increased user accountability

Water conservation

Increased capacity of other water sources

Leak detection

Identification of water overuse

Accurate pricing methods

Obstacles of Metering

■ Not important ■ Indifferent ■ Important ■ Very important ■ N/A

Limited financial resources

Limitations of current metering technologies

Lack of public support

Limited staff for maintenance/meter reading

Lack of previous experience with meters

Conversion of existing connections

Survey Results: Potable Water Systems

Have you considered the construction of a secondary water system in order to either allow agricultural supplies to be pressurized or to decrease demand on potable treated water supplies? This system would include a pressurized pipeline that would deliver water to residential customers for irrigation.

Yes	57%
No	43%

Are there other water providers within the limits of your system that provide pressurized secondary water?

Yes	50%
No	50%

If conversion of your system to a pressurized secondary system for residential users was feasible, how likely is it that you would make the conversion?

Very likely	23%
Likely	8%
Indifferent	31%
Not likely	31%
No chance	8%

Assuming that your water system decided to begin offering secondary water to residential customers, how important of an issue would the metering of individual connections be?

Very important	54%
Important	23%
Indifferent	15%
Not important	0%
Other	8%

Do you have any other comments?

Sandy City: Cost of secondary water would have to much less than treated water, not only to produce but to sell also.

Riverdale City: The cost of secondary water cannot exceed the cost of potable water because users may be tempted to cross connect in order to use the lower cost water.

Murray City: Regardless of where the water comes from conservations should still be considered.

Survey Results: Open Channel Irrigation Systems

Have you considered the construction of a secondary water system in order to either allow agricultural supplies to be pressurized or to decrease demand on potable treated water supplies? This system would include a pressurized pipeline that would deliver water to residential customers for irrigation.

Yes	67%
No	33%

Are there other water providers within the limits of your system that provide pressurized secondary water?

Yes	17%
No	83%

If conversion of your system to a pressurized secondary system for residential users was feasible, how likely is it that you would make the conversion?

Very likely	33%
Likely	17%
Indifferent	17%
Not likely	17%
No chance	17%

Assuming that your water system decided to begin offering secondary water to residential customers, how important of an issue would the metering of individual connections be?

Very important	50%
Important	33%
Indifferent	17%
Not important	0%
Other	0%

Do you have any other comments?

North Jordan Irrigation Company: North Jordan Irrigation Company is not a public utility. The stock holders have never expressed any interest in becoming a utility business.

Brooklyn Canal Company: Funding this conversion on our own is financially impossible. We have applied for federal funding from several sources and have been granted a long term loan from the Utah Water Resources Board.

APPENDIX C: FILTRATION COST ESTIMATION

Figure 5 is the result of a survey of many screen filter manufacturers throughout the United States. While many of the manufacturers contacted did not respond to cost estimation enquiries, Amiad Filtration Systems, Clemons Sales Corporation, Netafim USA, Orival Inc., and Tekleen Automatic Filters Inc. provided the following estimations based on a given flow rate, typical secondary water quality, and typical secondary system requirements. These estimations as shown in Table C1 were used to create the range of costs for centralized filtration cost estimation given in Chapter IV.

Table C1 Filtration Cost Estimations from Manufacturers

Manufacturer/Model	Micron	Flow (GPM)	Cost
Amiad 8" EBS	80	1000	\$22,000
Amiad 8" M108LP	80	1000	\$11,000
Amiad 16" Mega EBS	80	5000	\$110,000
Amiad 3/4" Plastic Filter	80	13	\$20
Amiad 1" Super Plastic Filter	80	30	\$58
Clemons 275A	400	275	\$855
Clemons 475A	400	475	\$1,142
Clemons 700A	400	700	\$1,264
Clemons 1200A	400	1200	\$1,564
Clemons 2000A	400	2000	\$2,272
Netafim 10-in Circulating Screen	80-200	2000	\$8,630
Netafim 10-in 19000 Series Screen	120-200	2250	\$9,216
Netafim 3/4" Standard Disc Filter	120	18	\$24
Netafim 1" Standard Disc Filter	120	26	\$80
Orival ORG Series 2-in	80-200	110	\$3,300
Orival ORG Series 8-in	80-200	1320	\$9,900
Orival OR-08-PS 8-in Filter	80-200	1320	\$12,000
Orival OR-18-PS 18-in Filter	80-200	6125	\$27,000
Orival OR-20-PSD 20-in Filter	100-200	8100	\$30,000
Tekleen Automatic Screen Filter	100,200	1000	\$10,000
Tekleen Automatic Screen Filter	100,200	3000	\$30,000
Tekleen Automatic Screen Filter	100,200	5000	\$50,000
Tekleen Automatic Screen Filter	100,200	7500	\$75,000

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T (303) 794-7711
F (303) 794-7310
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Denver, CO 80235-3098
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